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# Mechanisms behind the surprising observation of supra-thermal ions in fusion burning plasmas

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Although ignition had been achieved at the National Ignition Facility (NIF), recent observations of the experiments indicate novel physics that beyond theoretical predictions emerge, e.g., the neutron analysis of experiments has revealed deviations from the Maxwellian distributions in ion relative kinetic energies of burning plasmas, with the surprising emergence of supra-thermal deuterium and tritium (DT) ions that fall outside the predictions of macroscopic statistical hydrodynamic models. Via our newly developed hybrid-particle-in-cell code, incorporating the newly-proposed model of large-angle collisions, we infer that that this could be attributed to the increased significance of large-angle collisions among DT ions and particles in the burning plasma. Extensive and unprecedented kinetic investigations into the implications of large-angle collisions in the burning plasma have yielded several key findings, including an ignition moment promotion by the presence of supra-thermal ions below an energy threshold, and approximately twice the expected deposition o particles densities. The rationality of our findings is confirmed through the congruency between the neutron spectral moment analyses conducted by the NIF and our kinetic simulations, both highlighting progressively widening disparities between neutron spectral moment analyses and hydrodynamics predictions, which becomes more pronounced as the yield increases. Our kinetic simulations with large-angle collisions not only provide novel insights for experiment interpretation but also open new research opportunities for the largely unexplored regime of the nuclear burning plasmas, which are distinguished by their exceptionally high energy densities and hold immense potential for illuminating the intricate physics that underpins the evolution of the early universe.

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